N89-23568

WORKING GROUP WRITTEN PRESENTATION

SPACECRAFT CHARGING

Chairman: N. John Stevens
TRW

Issue Summary -

A. 1. Materials vulnerability and orbits. Spacecraft system performance

Spacecraft Charging Interactions Couple Environment Factors To System Operations Through Material Behavior.

The concern here is for possible interactions that result from the natural environment action on the spacecraft materials (e.g. GEO spacecraft charging) and for interactions caused by on-board system operations (e.g. high voltage solar arrays in low Earth orbits). Therefore, all orbits have possible spacecraft charging effects. This technology is still developing.

Specific effects on system performance are electromagnetic noise generation, anomalous electronic switching, electronic parts and thermal control coating degradation, dielectric electrical property change, power system losses and system failures.

These effects have all been documented in previous spacecraft flight data. Biggest data base is in GEO.

2. Correlation between theory and lab experience.

Previously defined charging interactions have been modeled and lab experiences indicate validity of models. This includes surface and bulk dielectric charging, effect of material configuration and some aspects of high voltage solar array/plasma interactions. The trouble with long-term predictive capability is that the systems are changing and what was tested in the past will not be flown in the future.

3. Can we predict for 10 or 30 years?

No, not with confidence. Present long-lived satellites are not the result of predictive confidence; they just occurred. In families of supposedly identical satellites, the lifetime varies because each is, in reality, individual satellites.

B. Facilities

There are facilities that can do pieces of this investigation. However, a facility has not been identified that can do all environments required simultaneously. Also, since these interactions are dependent on the configuration of materials, there is no facility that can handle the size of sample necessary to understand the very large spacecraft behavior in the space environment. Simulation

of actual space environments is very poor as is simulation of sample grounding. Facility ground is not the same as space. The available facilities exist at NASA-Lewis, Hughes, TRW, Boeing, G.E., and NASA-JSC.

C. 1. Synergism

Spacecraft Charging is the result of the other environmental factors acting on spacecraft materials. Therefore, all of the other factors are important:

- Atomic Oxygen - Changes insulators, films and coatings of properties.

- Meteoroid/Debris - Erodes and punctures dielectrics allowing structure potential electric fields to interact with plasmas.

- Trapped Radiation - Charges dielectrics and structure.

- Solar Radiation - Sunlit/shaded surfaces promote differential charging.

- Contamination - Changes surface properties.

Atomic oxygen and debris are low altitude phenomena (<1000 km for oxygen and 2500 km for debris); meteoroid and solar at all altitudes; trapped radiation at >800 km and polar orbits; contamination at all altitudes.

2. Testing of Synergism

Some aspects tested, but not all. Charging environments and solar effects documented by ground test and flight data (SCATHA). Pinholes in insulators in high voltage systems documented in laboratory. Influence of contamination on charged samples observed in laboratory tests and SCATHA flight data.

3. Available Facilities for Testing Synergism

Since these interactions are so all-inclusive, there are no facilities to do testing for all aspects of synergism.

D. Need for Space Experiments

The primary reason for space experiments is because the environment simulation is poor. The interactions to be studied require high energy electrons and protons, thermal plasmas, and sunlight for high orbits. For lower orbits the electrons and protons are replaced by atomic oxygen and debris. The physical size relationships that have to be studied, coupled with the power and voltages, demand space flight experiments.

This does not mean that only space flights must be conducted. Ground tests of individual aspects of interactions must be conducted. Analytical modeling of these tests must be validated and this modeling used to extrapolate to other interactions and size/power effects. This approach forms a data base to design meaningful spaceflight experiments. Flight experiments will have the proper environment, but instrumentation is limited and the experiment must be designed well to maximize the output.

E. Prioritized List of Experiments

The working group identified 10 interaction topics which are arranged in priority order in attached sheets. These fall into materials experiments (1,3,5,8) and materials related systems experiments (2,4,6,7,9 and 10). Since our interactions are normally prioritized against the impact on system performance, we should have had a better briefing on SDI system and technology requirements. It is recommended that this be done.

The experiments all should be run for extended periods of time in space. Some, like high voltage system interactions, can be done in days, while those dependent on radiation damage to materials require years to build up total dose effects. It would be nice to retrieve but it is not necessary. None of these experiments should be conducted within the Shuttle bay. It should be elevated away from the sides.

This general list of experiments can be further condensed into three:

1. Material Property Determination With Time in Space Environment With Material Under Electrical Stress

   This is a radiation, UV, meteoroid-type experiment requiring high altitudes and long life. Materials include conductors, dielectrics, composites, and thin film coatings.

2. High Voltage System Interactions With Plasmas

   This would be a low altitude experiment and would evaluate electric and magnetic stress as well as coupling in space. This would be a material configuration effect experiment.

3. Discharge Monitors

   High altitude or polar satellites should carry these monitors along with environment sensors to quantify effect of environmentally-induced effects.

F. Experiment Design

These are usually designed for the specific set of interactions desired. There probably can be a generic bus with interchangeable payloads. These can be tailored as piggyback, GAS or free-flyers. Only those experiments requiring low altitude information can be run at Shuttle/Space-Station Freedom altitudes. Those requiring radiation dose effects must be above 800 km.

G. Available Experiments

Concur with need for retrieving and reducing LDEF data.

Require future flight information at available altitudes.

1. Material performance under electrical stress and space radiation environments.

   No experiment to do this has been identified.

2. High Voltage Systems

a. SPEAR flight program underway (Space Plasma Experiments Aboard Rockets). These are very short duration, pulsed power experiments that provide information on system but not material behavior. Three minutes is not adequate to design multiyear life.

** b. NASA Planned Solar Array-Plasma Interaction Experiment. This must be conducted now. Such experiments have been planned in the past, started and then canceled. The data are mandatory.

c. Japanese plan experiment for 1992 time frame. No further information available.

SPACECRAFT CHARGING WORKING GROUP REPORT

CANDIDATE EXPERIMENTS

1. Material Property Changes With Electrical Stress and Time in Space Environment
2. High Voltage System Interactions
3. Thin-Film Coating Interactions
4. Discharge Characterization
5. "Tailored" Materials
6. Heavy Stressed Power System Dielectrics
7. Pulsed Power System Interactions
8. Composite Internal Noise Generation
9. Active Charge Control
10. "Radiation Belt" Charging

Interaction: Material Property Changes With Electrical Stress and Time in Space Environment

Why Problem:

- Stress Enhances Aging by Driving Solid State Chemical Interactions
- Radiation Induced Interface Failures
- Current Spacecraft Behavior Starting To Be Understood but Materials and Operating Conditions Changing
- Lifetime Extended

Ground Test/Theory Correlation:

- Dielectric Community Working
- Short Term Testing Without Space Environment

What Is Still Needed: Materials Testing To Establish Range of Interaction

Why Require Spaceflight:

- Need Space Environment to Verify
- High Altitudes or Polar for Radiation
- Time in Environment

Supporting Work: Dielectric Community
Not Directed Towards Space Applications

Interaction: High Voltage System Interactions

- High Voltage Solar Arrays
- Structure Collection in Plasmas
- Scaling Laws for Size, Voltage, Power, Frequency
- Sheath Effects

Why Problem: System Floats Electrically in Plasma Environment
Breakdowns in High Voltage Systems

Ground Test/Theory Correlation: Small Scale Sample Correlates With Theory.

What Is Still Needed: Size, Voltage, Power, Frequency Scaling.

Why Require Spaceflight: Need Complete Space Environment.
Can't Simulate On Ground

Supporting Work: Ground Support Work
Japanese Space Experiment

Interaction: Thin-Film Coatings
Stability of Thin-Film Optical and Electrical Coatings in Space Environment

Why Problem: Applied for Specific Optical or Electrical Purpose
Charging Interaction Coupled With Sputtering or Contamination May Destroy

Ground Test/Theory Correlation:

- Short-Term Testing
- Flight Data Not Instrumented For Detailed Examination

What Is Still Needed:

- Identification of Coatings

Why Require Spaceflight:

- Need Space Environment

Interaction: Discharge Characterization

Sources - Conditions for Discharge Initiation, High Power
Character - Frequency, Amplitudes, Rep Rate, Transfer Function and Changes With Time in Space

Why Problem: Protection of System Circuits Depends on Knowledge of Discharges

Ground Test/Theory Correlation:

- Deducing Discharge Behavior in Space by Effect
- Characteristics Not Repeatable

What Is Still Needed:

- Theory and Test Correlation

Why Require Spaceflight: Need Total Environment and Spacecraft Configurations

Interaction: "Tailored" Materials

- Materials Developed for Properties To Minimize Charging Levels
- Conductivities in Range 10^{-8} to 10^{-10} S/cm^2

Why Problem: Can Mitigate Charging Concerns

Ground Test/Theory Correlation:

- Quasi-Conductive Materials Under Development

What Is Still Needed:
- Better Materials for This Application
- Demonstrate Stability in Space Environment

Why Require Spaceflight: Demonstrate Behavior in Space Environment

Supporting Work: GSFC, VA. Tech

Interaction: Heavy Stressed Power System Dielectric SDI Applications Under High Voltage and Large Current

Why Problem: Strong Electrical Stress and Induced Magnetic for Reduce Breakdown Thresholds

Ground Test/Theory Correlation:

- Pieces Under Study

What Is Still Needed: Combined System Effects
Space Environment Demonstration

Why Require Spaceflight: Total Space Environment Effect
Time in Space

Interaction: Pulsed Power Interaction
System Dynamic Response to 1 to 100 μsec Power Pulse

Why Problem: Behavior in Plasma Uncertain
Affects System Performance
Flashover

Ground Test/Theory Correlation: Theory Being Developed

What Is Still Needed: Theory and Test Demonstration

Why Require Spaceflight: Need Space Environment
Radiation Environment Important

Supporting Work: SPEAR II
Texas Tech and Maxwell (Testing)

Interaction: Noise Generated in Composites
Space Induced Charging Coupled With
Radiation Generates Noise in Materials

Why Problem: RF Noise Can Couple Into Communications and Sensors

Ground Test/Theory Correlation: Measure RF Levels in Small Samples Under Electrical Stress and Radiation Theory Adequate but Number of Pulses Unknown

What Is Still Needed: Pulses Expected in Samples Scaling

Why Require Spaceflight: Need Spaceflight Environment
Auroral or High Altitude
Can Be Added to Existing S/C Systems Having R.F. Detection

Interaction: Active Charge Control Interactions

Why Problem: Mitigation Technique but Can Degrade Coatings by Bombardment - Time Effect

Ground Test/Theory Correlation: Short Term Testing
Model Exists but Not Validated

Why Require Spaceflight: Long Term Study in Space Without Walls

Supporting Work: AFGL Charge Control System (Xenon)
IAPS (Mercury)

Interaction: "Radiation Bolt" Charging
Energetic Proton and Electron Environment - Variable in Orbits

Why Problem: Upsets Seem To Occur on GPS
No Charging Model Evaluation

Ground Test/Theory Correlation:
Should Be Able To Treat but Hasn't Been Yet

What Is Still Needed: Evaluation of Effect of Environment

Why Require Spaceflight: Need Environment and Time In Space

SPACECRAFT CHARGING WORKING GROUP REPORT

SUMMARY -

- Identified Interactions That Would Affect System Performance
- Better Definition of System/Missions Required
- General Approach for This Area:
  - Small Scale Ground Tests
  - Modeling of Interaction
    - Understanding
    - Scaling
  - Flight Verification Test